PARAMETRIC STRESS ANALYSIS OF HELICAL GEAR USING FEA

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Abstract - *Gears are used for transmitting power between the shafts. It is one of the best methods for transmitting torque, power, angular velocity and motion. For transmitting motion and power between intersecting shafts which is parallel and non-parallel helical gear is used. This study investigates the maximum contact stress, which improves the load-sharing capacity of a helical gear set with localized bearing contact, by means of finite element analysis (FEA). The finite element method is proficient to supply this information with reasonable accuracy. So an accurate estimation of maximum contact stress becomes important to improve the load carrying capacity and reduce the tooth failure at the contact surface. In the gear design, the bending stress and surface strength of the gear tooth are considered one of the main contributors for the failure of the gear in a gear set. In this paper, contact stresses are calculated by using Finite element analysis. Solid Works 2016 software is used to generate the 3-D solid model of the helical gear. Ansys software package is used to analyze the stresses. Contact stresses are calculated by using the multi-pair contact model (MPCM) contact stress method. The actual load shared among the paired teeth is also calculated by the MPCM method.*

***Key Words*: FEA (Finite element analysis), LSR (Load Sharing Ratio), LPTC (Lowest Point of Tooth Contact), HPTC (Highest Point of Tooth Contact), MPCM (Multi-Pair Contact Model), MPC (Multi Point Constraint).**

1. INTRODUCTION

Gears are used for transmitting power between the shafts. It is one of the best methods for transmitting torque, power, angular velocity and motion. The helical gear is used to transmit motion and power between parallel, non-parallel and intersecting shafts. In this thesis, we're going to be discussing helical gears and the forces that are transmitted through them. A helical gear is similar to a spur gear but in helical gear has a helix angle to the central axis of the shaft. The central axis (Z) is the axis that goes through the hole in the middle of the gear and there is some angle with respect to that axis which is called the helix angle. So that helical gears are great because it has point and line contact and it allows you to have for more gentle engagement. This study investigates the maximum contact stress, which improves the load-sharing capacity of a helical gear set with localized bearing contact, by means of finite element analysis (FEA). In the gear design, failure of the gear in a gear set stress and surface strength are considered to be one of the main reason and it will optimize for get maximum life for gear tooth.

In this paper, contact stresses are calculated using an analytical method as well as Finite element analysis. Solid Works 2017 software is used to generate the 3-D solid model of the helical gear. Ansys software package is used to analyze the stresses. Contact stresses are calculated by using a multi-point constraint method (MPCM). The actual load shared among the paired teeth is also calculate by MPCM method. The finite element method is proficient to supply this information with reasonable accuracy. So an accurate estimation of maximum contact stress becomes important to improve the load carrying capacity and reduce the tooth failure at the contact surface. The actual load shared among the paired teeth is not the same which is calculated by the multi-point constraint method (MPCM) method. In view of this, the main purpose of this work is by using an analytical approach and different parameters to develop a theoretical model of the helical gear.

Gears are used for transmitting power between the shafts. It is one of the best methods for transmit torque, power, angular velocity and motion. Gears are one of the most critical components in mechanical power transmission systems. Helical gear is used to transmit motion and power between parallel, non-parallel and intersecting shafts. Gears are mostly used to transmit torque and angular velocity.

The rapid development of industries such as shipbuilding, vehicles and aircraft require advanced application of gear technology. In this thesis we're going to be discussing helical gears and the forces that are transmitted through them so a helical gear is similar to a spur gear except that the teeth are at a helical angle with respect to the central axis of the shaft. The central axis (Z) is the axis that goes through the hole in the middle of the gear and there is some angle with respect to that axis which is called helix angle. So that helical gears are great because they allow you to get more surface area of a tooth to have that line of contact and it allows you to have for more gentle engagement.

This study investigates the maximum contact stress, which improve load-sharing capacity of a helical gear set with localized bearing contact, by means of finite element analysis (FEA).In the gear design, the bending stress and surface strength of the gear tooth are considered to be one of the main contributors for the failure of the gear in a gear se

2. MATERIAL PROPERTY

For helical gear basic materials used range from steel, cast iron and different hard materials. AISI 8620 steel is used for this analysis, which have sufficient harden ability. The alloy steel contain 0.18-0.23 carbon, 96.9-98.02 iron, 0.4-0.7 nickel, 0.7-0.9 Mn and 0.15-0.35 Si. The other designation of this material is shown in Table-1.

Table -1: Material Property

Elastic Modulus	210000	N/mm²
Poisson's Ratio	0.28	N/A
Shear Modulus	79000	N/mm²
Mass Density	7700	kg/m²
Tensile Strength	723.8256	N/mm²
Yield Strength	620.422	N/mm²
Thermal Expansion	1.3e-005	/K
Thermal Conductivity	50	W/(m·K)
Specific Heat	460	J/(kg·K)

3. DESIGN PARAMETERS

For contact stress analysis of helical gear pair, the understanding of the helical gears geometry is necessary. The complex geometry of helical involute gears leads to the gradual meshing of pinion tooth with wheel tooth. The law of gearing states the condition, which must be satisfied by the gear tooth profiles to maintain a constant angular velocity ratio between the two gears. The process of drawing the helical tooth flanks for Finite Element Contact Analysis is based on the drawing of involute tooth profile and sweeping this profile along the helix line.

Table- 2: Design Parameter for Solid Model

Parameters	Value
Number of teeth helical gear	20
Helix angle	12
Module, normal (mm)	1 & 1.25
Pitch	1mm
Normal pressure angle	20 deg
Face width (mm)	8.4
Load applied	10 N-m
Addendum	1
Dedendum	1.25
Hole depth	2.25
Transverse pressure angle	20.4103 deg
Transverse pitch	0.978148 deg
Transverse tooth thickness	1.60589
Gear Ratio (teeth/diameter)	10mm

4. SOLID MODELING OF GEAR PAIR

In the first stage of model designing of our gear using the metric module system although we could just as easily create a gear using the diametral pitch in the ANSI system. The distance between centers the gear ratio or the number of teeth or the diameter or pitch or the module. In our case and in this case we want to create a one-millimeter module gear with 20 teeth. To add a global variable we do this to the equations of the file as shown in Table- 3. Although we'll notice the equations folder we have been added some equation to this file. Yet in any file, we can access any feature tree items. The global variables need to be encapsulated by quotes. We're going to enter the module value 1 previously mentioned it is one millimeter.

Table- 2: Variables for Solid Model

Name	Value/Equation	Evaluates
Global Variables		
"Module"	= 1mm & 1.25mm	1mm
"Number of Teeth"	= 20	20
Equations		
"Addendum Circle"	(Number of teeth+2) × Module	22mm
"Pitch Circle"	Module × Number of Teeth	20mm
"Whole Depth"	Module × IIF (Module = > 1, 2.25)	2.25mm
"Fillet"	Module × 0.3	0.3mm
"Circular pattern"	Number of teeth	20
"Angle of involute from center"	180/Number of teeth	9deg
"Helix Angle"	=12 deg	12deg

The outside diameter, the base circle, the root diameter etc. The pitch diameter is one of the most important features of a gear. It defines where two gears interact with each other and set the stage for the tooth profile itself. SolidWorks allows you to enter equations on the fly to solve for equation by simply pressing the equals key. Similarly, we create the solid model for module 1.25mm. The process of drawing the helical tooth flanks for Finite Element Contact Analysis is based on the drawing of involute tooth profile and sweeping this profile along the helix line. The addendum is the distance between the pitch circle and the outer circle at the upper half of the tooth, and dedendum will be the lower portion.

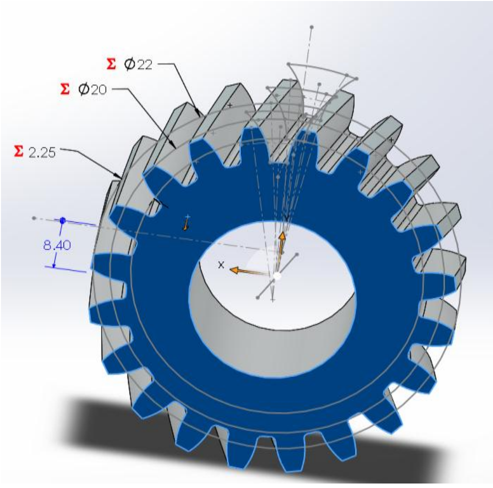

Figure -1: Solid Model with involute profile

Here Fig- 1 shows the configuration of gear pairs of helical gears. Suppose there are two gears mounted on two shafts. One is the driving shaft and another is driven. It's rotating in the clockwise direction by power. As a result, rotation of this shaft on which it is mounted, so rotation and torque are transmitted from one shaft to another shaft through a pair of gears.

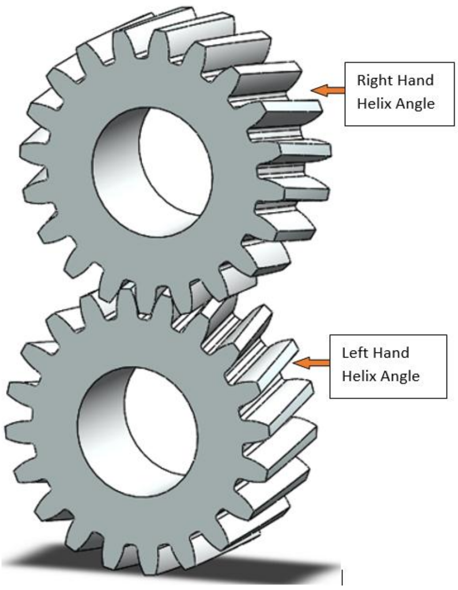

Figure- 2: Helical Gear Pair

The line of action of the teeth that means the contact point between the teeth conjugate teeth will follow the path in a straight line. So that the forces will not fluctuate and the angle between these two, the line of action and the common tangent will constitute. The angle very important called pressure angle and the circular pitch that is the distance between two conjugative teeth of the gear at a given point.

5. RESULT FROM FEA AND ANALYSIS

Meshing of Solid Model in FEA: The contact stress analysis using the finite element to get accurate results. The solid element is broadly grouped under the tetrahedral, hexahedral family of the element. In this analysis, the 3D eight nodded brick element is chosen from hexahedral family for the element representation. This three-dimensional iso-parametric formulation element is chosen because it takes care of a shift in cross-section along the axis of the gear. To get better and accurate results mapped meshing is used instead of free meshing.

Result from Ansys: The solid model of helical gear is analyzed in Ansys V18.1. The load sharing ratio of the helical gear pair teeth in one mesh cycle can be calculated by the average load shared by teeth during the mesh cycle of gear. The load shared among the contact element of the paired teeth can be obtained by applying force 10 MPa on the nodes of inner radius of the rim in tangential direction and constrained in the remaining direction of the pinion and the gear is also constrained in each direction because of which contact load is generated in each period of the contact element. The result for Von-Mises stress calculated by Ansys Software package for Module 1 which is shown in Fig- 3

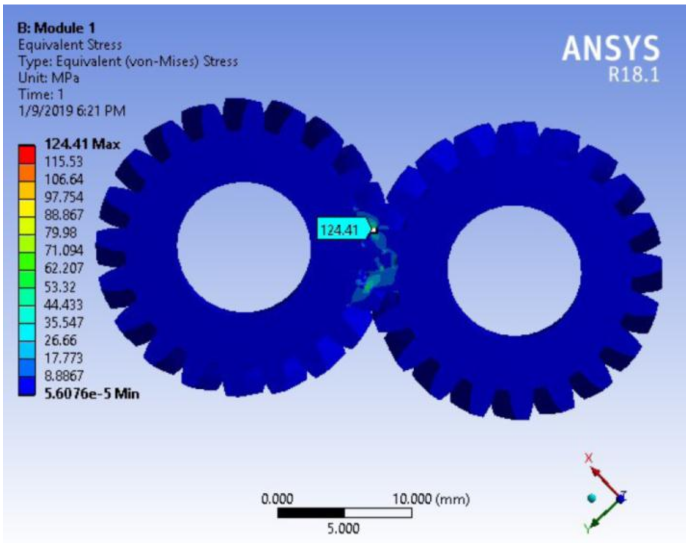

Figure- 3: Von-Mises Stress for Module 1

The Von-Mises stress calculated by using Ansys software V18.1 for module 1.25 which is shown in Fig-4. The contact stress analysis of helical gear is also performed in the same manner as the load sharing ratio. The maximum contact stress along the face width of the gear is determined at each contact position starting from the start of engagement at the rear face to the end of the engagement at the front face of the gear. The maximum contact stress values determined by the load sharing ratio for two face width for one mesh cycle.

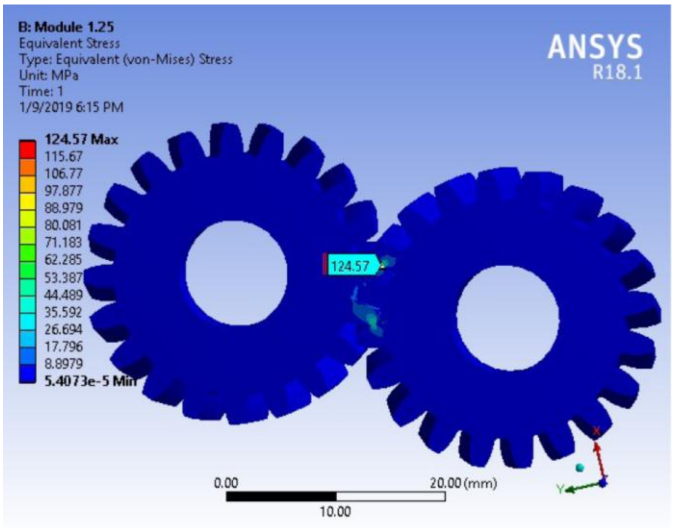

Figure- 4: Von-Mises Stress for Module 1.25

Table- 3: Output from Ansys (Von-Mises Stress)

Module Type	For Module 1	For Module 1.25
Von-Misses Stress	124.41 MPa	124.57 MPa

Load Sharing Ratio: The load sharing ratio of the pair of helical gear teeth in one mesh cycle can be calculated by the average load shared by the teeth during the mesh cycle of gear. The load shared among the contact element of paired teeth can be obtained by applying torque on the nodes of inner radius of the rim in tangential direction and constrained in the remaining directions of the pinion and the gear is also constrained in each direction because of which contact load is generated in each paired of contact element. The load sharing ratio of pair of gear teeth for face width values of helical gear as shown in figure respectively. Form load sharing plots of helical gear for the three modules of gear pair, it is observed that increase in face width and module increases the three tooth contact region and decrease the two contact region. Which will comparatively less contact stress in contact region along the face width.

Table- 4: Solution Parameter of Solid Model

Volume	3875 mm³
Mass	2.9838e-005 t
Nodes	143948
Elements	30378

$$LSR_1 = \frac{\text{Contact load at pair 1}}{\text{Contact load at pair 1} + \text{Contact load at pair 2} + \text{Contact load at pair 3}}$$

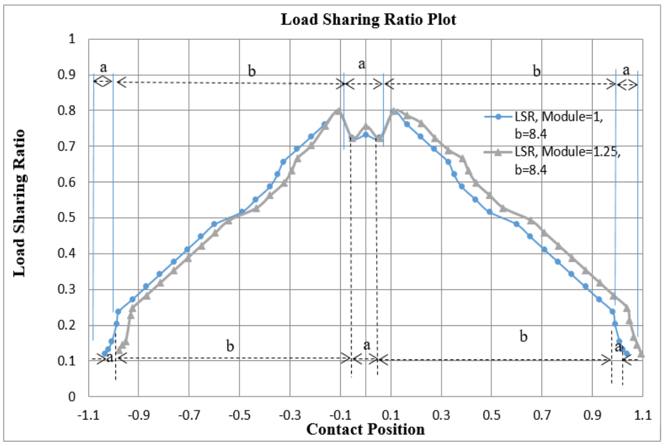

Figure- 5: LSR Vs Contact Position (X/Pbt) plot for module 1 & 1.25

6. CONCLUSIONS

The contact stress analysis of the helical gear pair by using the load sharing ratio in FEM analysis. The maximum contact stress along the face width of the gear is determined at each contact position starting from the engagement at the rear face to the end of the engagement at the front face of the gear. The maximum contact stress values are determined by the load sharing ratio for two face width for one mesh cycle. It is observed that the maximum contact stress in the contact region of the helical gear is increase from root of the tooth at the rear face of gear to pitch point at the front face of the tooth of gear and decreases from pitch point at the front face of tooth of gear to tip of the tooth at the front face of the gear. The maximum contact stress is developed because of the contact pressure developed at the line of contact along the face width of gear. The maximum contact stress increases from root to pitch point because load sharing ratio increase from root to pitch. Similarly, the maximum contact stress decreases from root to tip as load sharing ratio decreases from pitch point to tip.

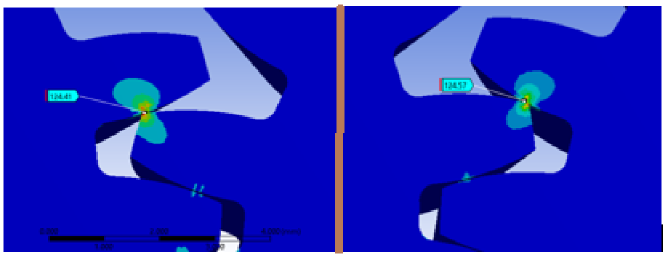

Figure- 6: Maximum Contact Stress Module 1 & 1.25

The attempt is made to determine the contact stresses in helical gear by considering the load sharing ratio between the pair of teeth in simultaneous contact. The following observations are made from the FEM analysis of helical gear.

- The maximum contact stress in the contact region of helical gear is developed at the pitch point of helical gear because of high load sharing ratio.

- The contact stress near tip and the root is less as compared at pitch point because of less load sharing ratio.
- The maximum contact stress is decreases with the increase in the face width of helical gear.
- The maximum contact stress is increase in module 1.25 as compare to module 1.

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